Diffraction at ALICE

- ALICE detector
- Diffractive gap trigger in ALICE
- Pomeron signatures in p-p
- Odderon signatures in p-p
- Signature of gluon saturation in diffraction
- Conclusions, outlook

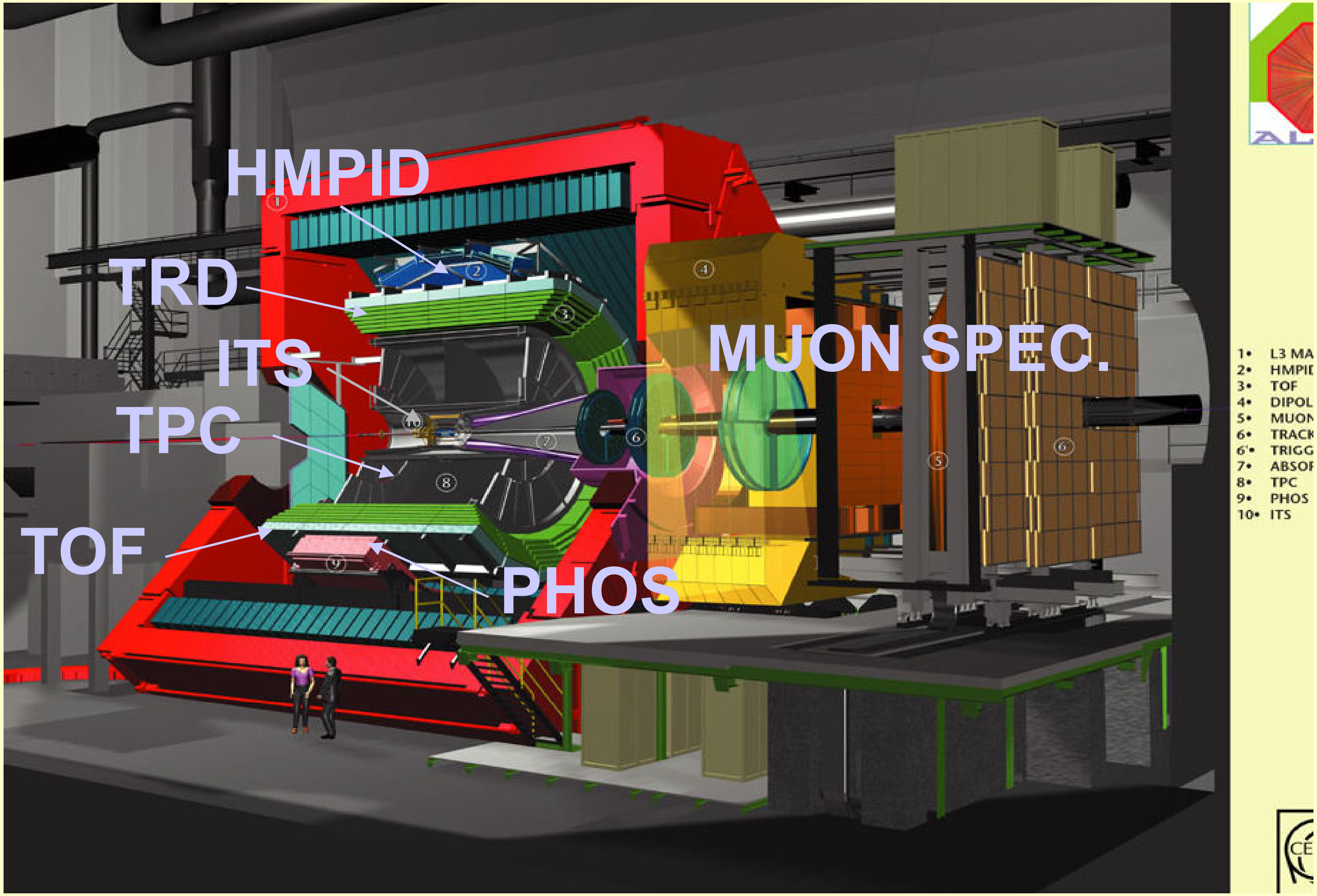
The ALICE experiment

Acceptance central barrel

$-0.9 < \eta < 0.9$

Acceptance muon spectr.

$-2.5 < \eta < -4.$



ALICE diffractive gap trigger

→ additional forward detectors

(no particle identification)

$$1 < \eta < 5$$
$$-4 < \eta < -1$$

→ definition of gaps η_+, η_-

p-p luminosity L = 5×10^{30} $cm^{-2}s^{-1}$:

→ one interaction/ 80 bunches

diffractive L0 trigger (hardware):

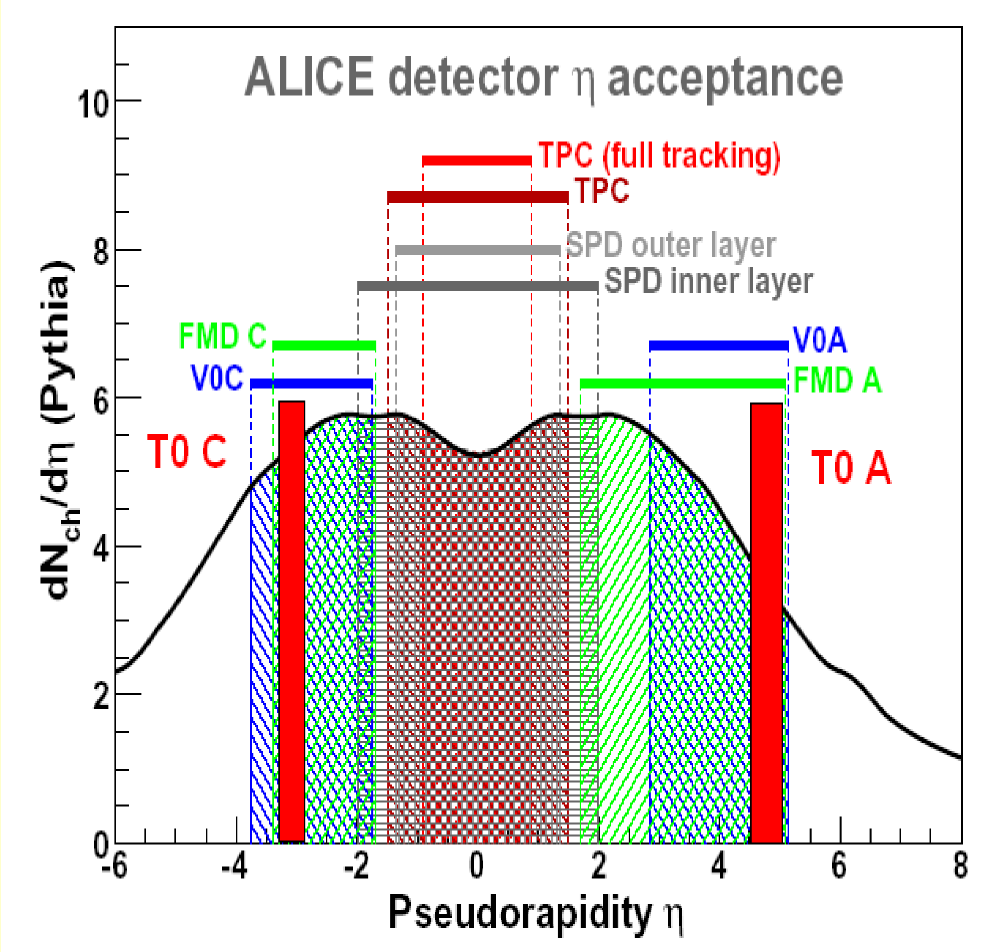
Pixel or TOF mult (central barrel)

gap η_+: $3 < \eta < 5 \rightarrow \Delta\eta \sim 0.5$

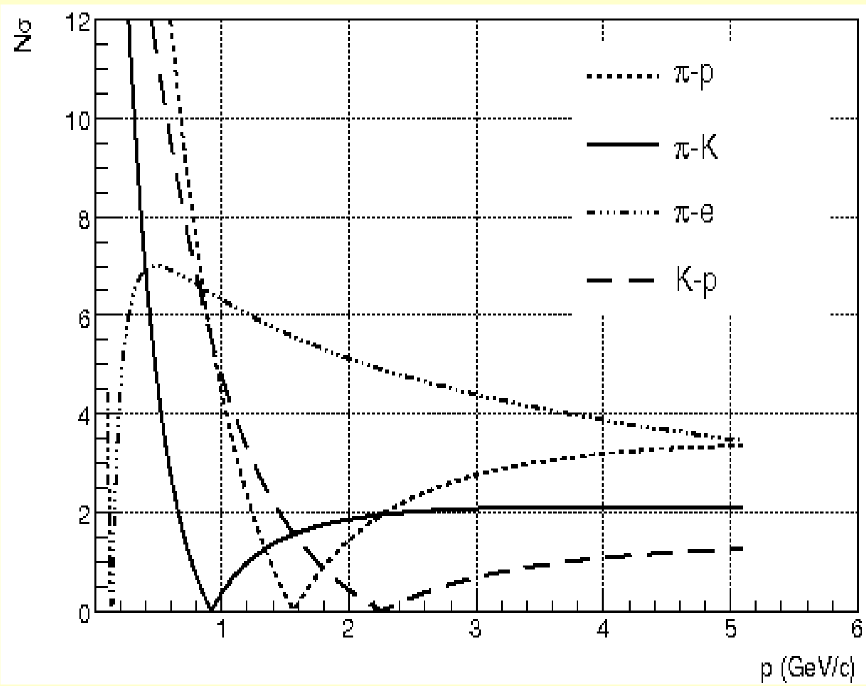
gap η_-: $-2 < \eta < -4 \rightarrow \Delta\eta \sim 0.5$

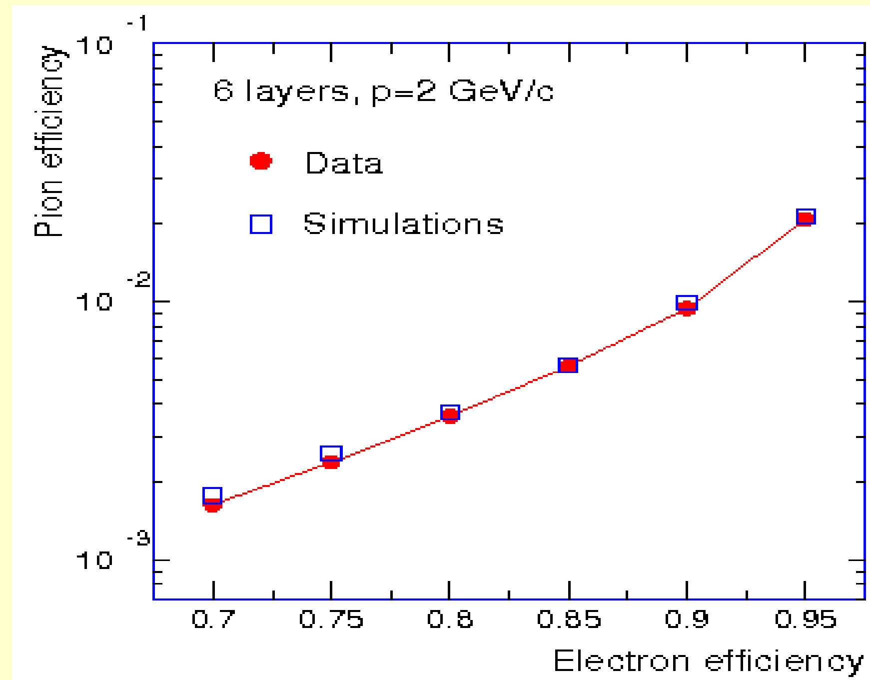
high level trigger (software):

$$-3.7 < \eta < 5$$



ALICE central barrel particle identification





Particle identification by dE/dx in central barrel as function of momentum

In addition time of flight information for non-relativistic momenta

Electron-pion separation in TRD as function of momentum

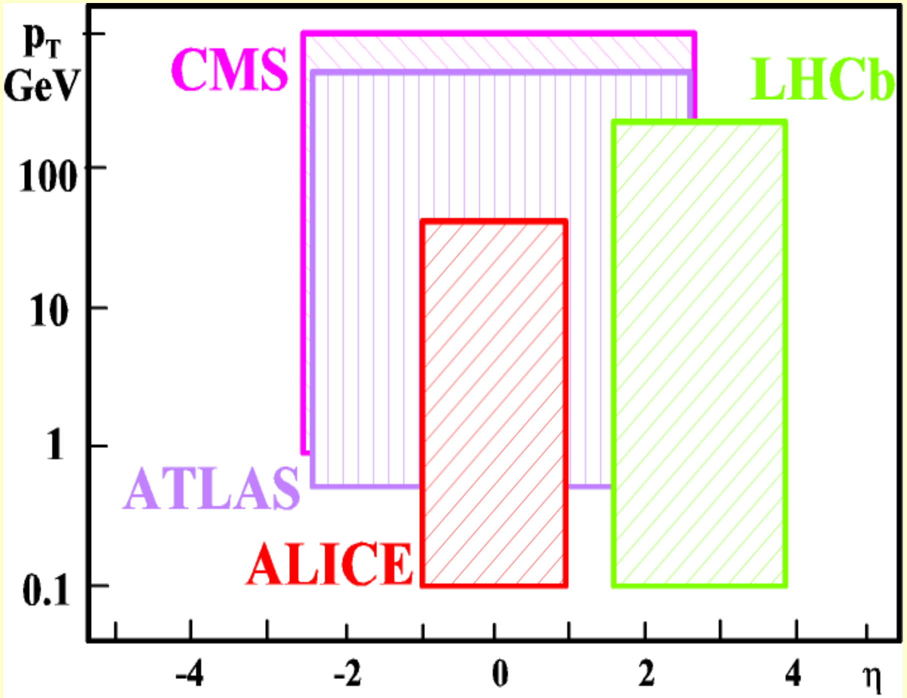
→identify vector mesons by e^+e^- decay

ALICE central barrel comparison to other LHC detectors

low magnetic field

	Magn. field (T)	P_T cutoff GeV/c	Material x/x0 (%)
ALICE	0.2-0.5	0.1-0.25	7
ATLAS	2.0	0.5 (0.08)	20
CMS	4.0	0.75 (0.2)	30
LHCb	4Tm	0.1	3.2

η–pt acceptance



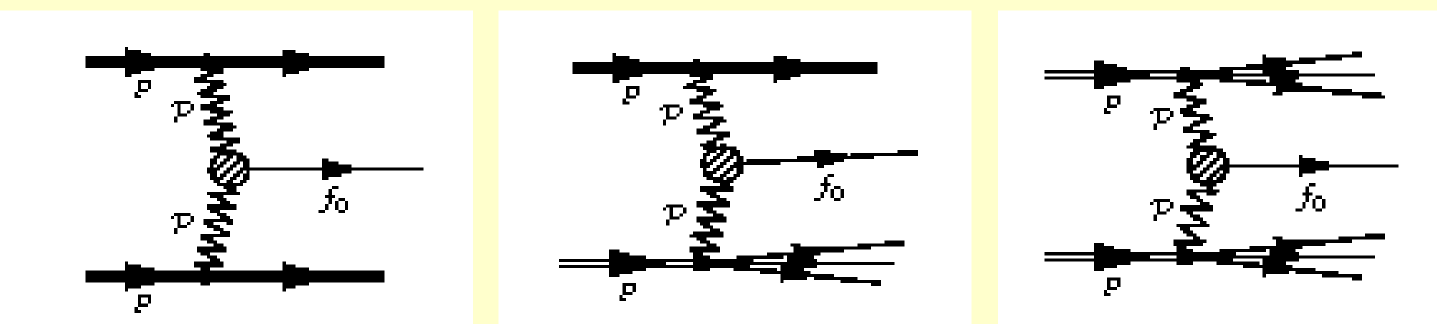
→ low p_T trigger ?

→good ALICE acceptance for ϕ, J/Psi, Ψ by electron decays (p_T > 0 MeV/c)

ALICE forward calorimeter

- **neutron calorimeter on each side**
  - **Placed at 116 m from interaction region**
  - **Measures neutral energy at 0°**
- **Diffractive events with and without proton breakup:**
  - **pp → ppX : no energy in zero degree calorimeters**
  - **pp → pN*X, N*N*X : energy in one or in both calorimeters**

Identify the three topologies:



A B C

$$\frac{\sigma_A}{\sigma_B} \equiv f\,(x_1, x_2, ..)\frac{\sigma_{elast}}{\sigma_{SD}}$$

$$\frac{\sigma_B}{\sigma_C} \equiv g\,(x_1, x_2, ..)\frac{\sigma_{SD}}{\sigma_{DD}}$$

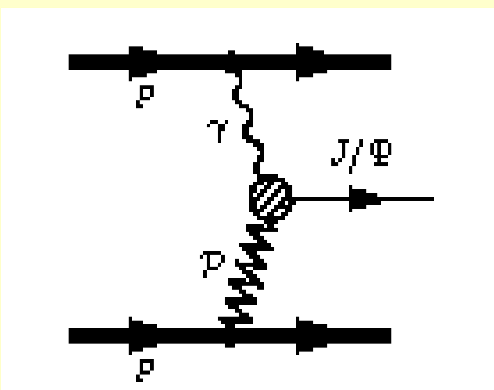
$$\frac{\sigma_A}{\sigma_C} \equiv h\,(x_1, x_2, ..)\frac{\sigma_{elast}}{\sigma_{DD}}$$

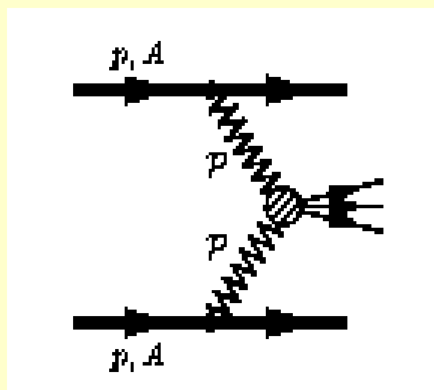
→ what are $f(x_i)$, $g(x_i)$, $h(x_i)$?

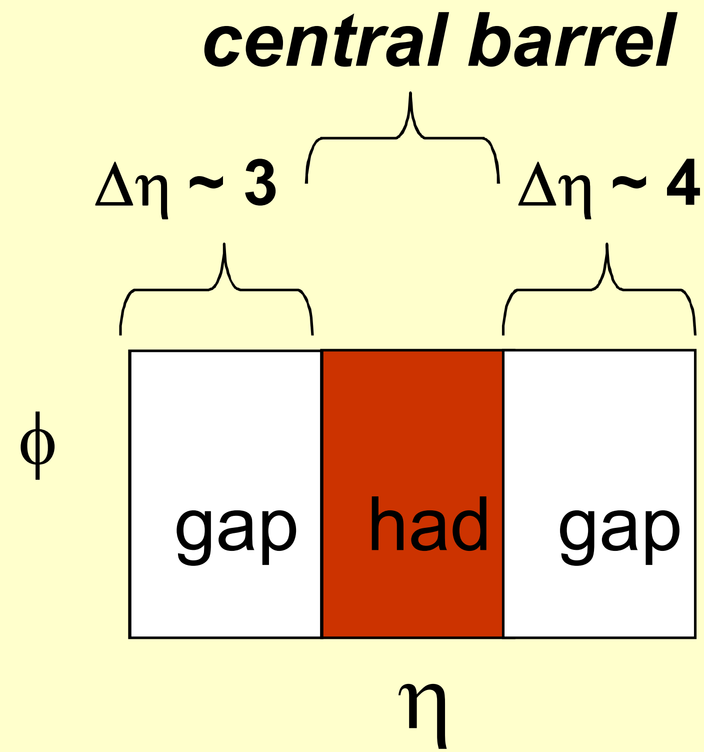
ALICE diffractive physics

- ALICE acceptance matched to diffractive central production:

  γ-pomeron, double pomeron, odderon-pomeron







Data taking:

pp @ L = $5x10^{30}$ $cm^{-2}s^{-1}$ $(\rightarrow \frac{d\sigma}{dy}\Big|_{y=0} \sim nb)$

pPb @ L = 10^{29} $cm^{-2}s^{-1}$

PbPb @ L = 10^{27} $cm^{-2}s^{-1}$

Pomeron signatures

POMERON: C = +1 part of gluon color singlet exchange amplitude

Compare pomeron-pomeron fusion events to min bias inelastic events

1) Enhanced production cross section of glueball states: *study resonances in central region when two rapidity gaps are required*

2) Slope pomeron traj. $\alpha' \sim 0.25 GeV^{-2}$ in DL fit, $\alpha' \sim 0.1 GeV^{-2}$ in vector meson production at HERA, t-slope triple pom-vertex < $1 GeV^{-2}$

$\rightarrow$ mean k_t in pomeron wave function $\alpha' \sim 1/k_t^2$ probably $k_t > 1$ GeV

$\rightarrow$ *$\langle p_T \rangle$ secondaries in double pomeron > $\langle p_T \rangle$ secondaries min bias*

3) $k_t > 1$ GeV implies large effective temperature

$\rightarrow$ *K/π, η/π, η'/π ratios enhanced*

Central exclusive $\pi^+\pi^-$ production at $\sqrt{s}$ = 63 GeV

Data taken by Axial Field Spectrometer at ISR $\sqrt{s}$ = 63 GeV (R807)
very forward drift chambers added for proton detection

$p \longleftarrow \pi^+\pi^- \longrightarrow p$

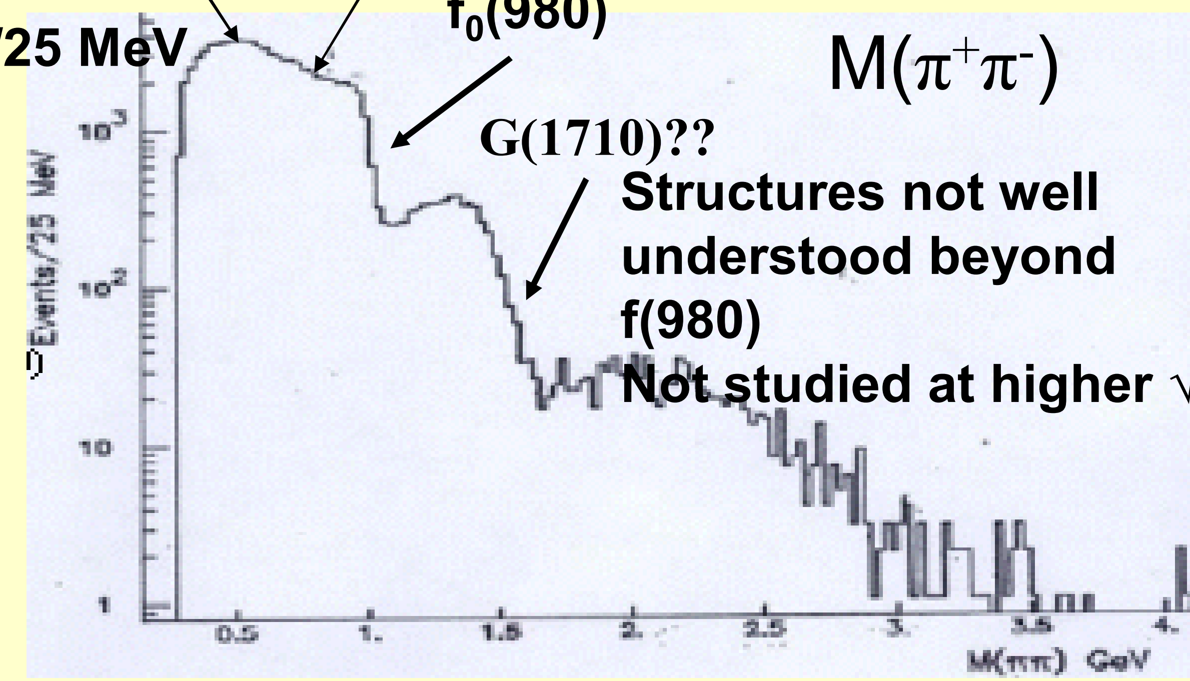
T.Akesson et al 1986:

Flavour independence: equal numbers of $\pi^+\pi^-$ and K^+K^- pairs for masses larger than 1 GeV

f_0(600)=σ **no ρ**

3500 events/25 MeV

f_0(980)



$M(\pi^+\pi^-)$

G(1710)??

Structures not well understood beyond f(980)

Not studied at higher $\sqrt{s}$

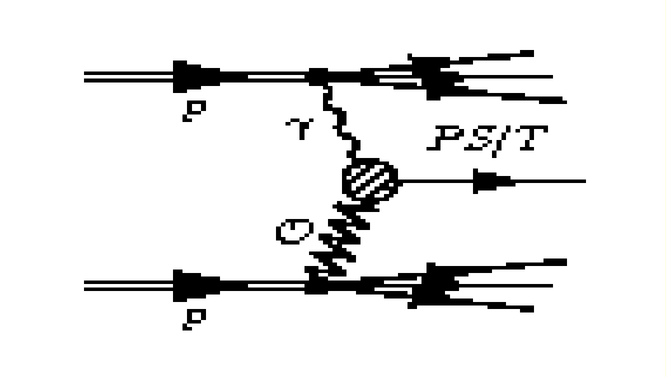
Signature Odderon cross section

ODDERON: C = -1 part of gluon color singlet exchange amplitude

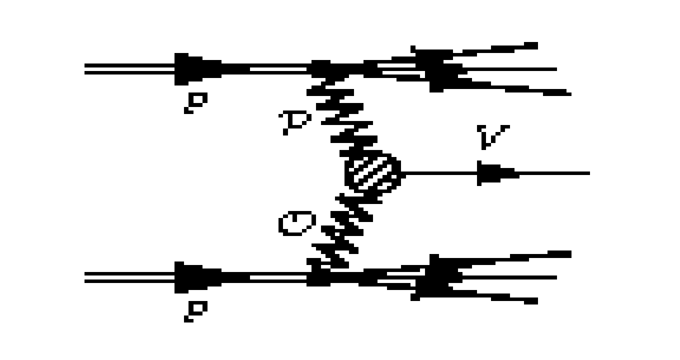
Look at exclusive processes with rapidity gaps

Examples:

diffractive pseudo scalar and tensor meson production:
C = +1 states



diffractive vector meson production: C = -1 states



→ *measure cross sections*

The hunt for the Odderon

- Production cross sections in pp at LHC energies
  - diffractive production: $\pi_0, \eta, \eta_c (J^{PC} = 0^{-+}),\ a_2(2^{++})$

    → contributions from Photon-Photon, Photon-Odderon, Odderon-Odderon
  - Look for diffractive J/Ψ production: $J^{PC} = 1^{--}$

    → Photon-Pomeron, Odderon-Pomeron contributions

→ such an experimental effort is a continuation of physics programs carried out at LEP (γγ) and HERA (γ-Odderon)

Diffractive J/Ψ production in pp at LHC

- First estimates by Schäfer, Mankiewicz, Nachtmann 1991
- pQCD estimate by Bzdak, Motyka, Szymanowski, Cudell
  - Photon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0}$ ~ 15 nb (2.4 - 27 nb)
  - Odderon: t-integrated $\left.\frac{d\sigma}{dy}\right|_{y=0}$ ~ 0.9 nb (0.3 - 4 nb)

At L = 5×10^{30} $cm^{-2}s^{-1}$:

→ ***0.15 J/Ψ in ALICE central barrel in 1 s, 150k in 10^6 s***

→ ***9000 in e^+e^- channel in 10^6 s***

→ identify Photon and Odderon contribution by analysis p_T-distribution (Odderon harder p_T spectrum)

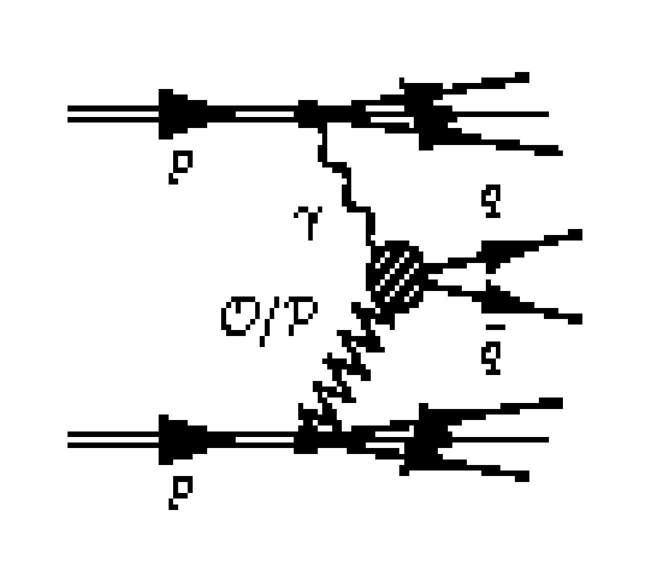
Signature Odderon interference

- Cross sections contain squared Odderon amplitudes

→ ***Odderon-Pomeron interference !***

$$d\sigma \sim |A_\gamma (A_P + A_O)|^2 \, d^N q$$

$$\sim |A_P|^2 + 2\mathrm{Re}(A_P A_O^*) + |A_O|^2$$



→ ***look at final states which can be produced by Odderon or Pomeron exchange***

→ ***find signatures for interference of C-odd and C-even amplitude***

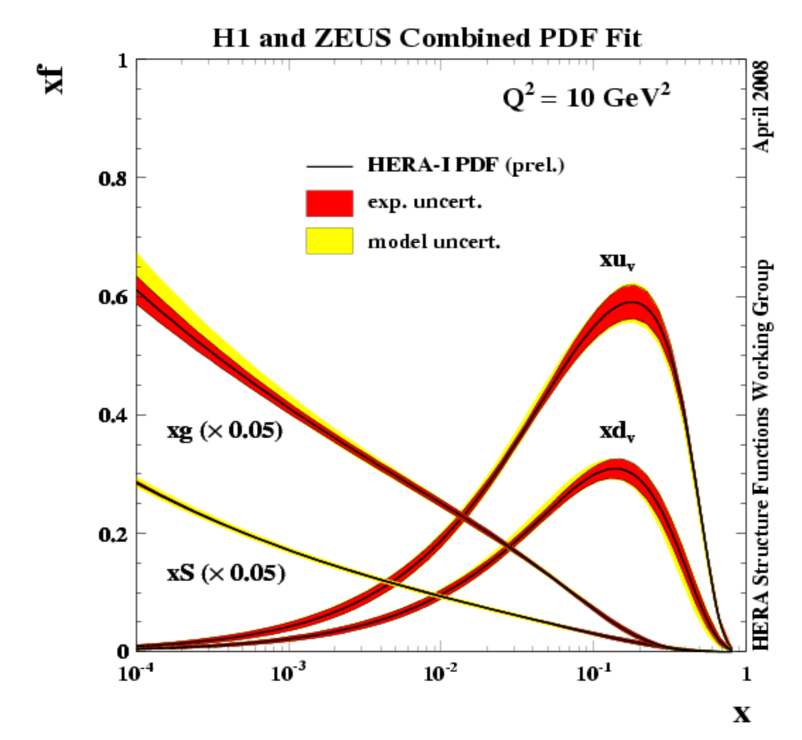
Interference signal

- Interference effects (relative contribution $C=-1$)
  - Asymmetries in $\pi^+\pi^-$ and K^+K^- pairs ($C=\pm1$) in continuum
  - → charge asymmetry relative to polar angle of π^+ in dipion rest frame
  - → fractional energy asymmetry in open charm diffractive photoproduction

  → asymmetries in HERA kinematics estimated 10 % - 15 %

Gluon saturation

- Fits of parton densities xu_v, xd_v, xg, xS to HERA data



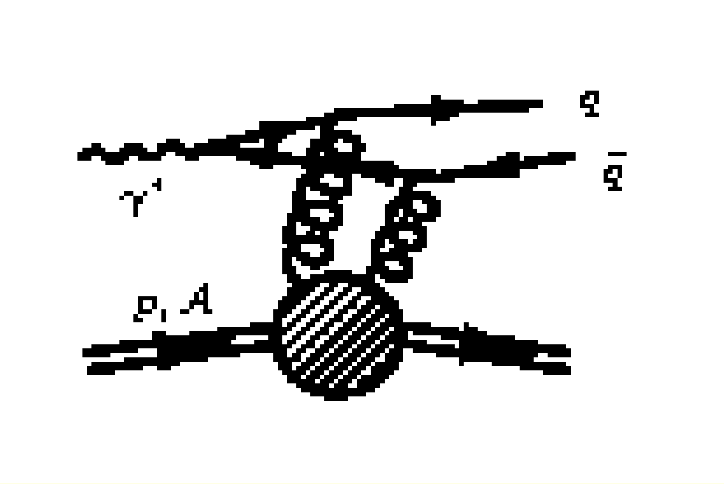
- How does gluon density behave at low x ?

- Where does gluon saturation set in ?

- Are there observables which are sensitive to gluon saturation ?

Heavy quark photoproduction in pp @ LHC

- Photoproduction of $Q\overline{Q}$
  - photon fluctuates into $Q\overline{Q}$,
  - Interacts as color dipole



$$\sigma_{dip}(x, r^2) = \sigma_0\{1 - \exp(-\frac{r^2}{4R_0{}^2(x)})\}$$

Golec-Biernat, Wuesthoff 1999

$$R_0(x) = \frac{1}{GeV}\left(\frac{x}{x_0}\right)^{\lambda/2}$$

σ_0, λ from fits of F_2 with $x < 0.01$

$\longrightarrow$ σ_{dip} saturates when r ~ $2R_0$

$Q\overline{Q}$ -production cross section in pp-collisions

$$\sigma(pp \to Q\overline{Q}pp) = 2\int \frac{dn_\gamma^p(\omega)}{d\omega}\sigma_{\gamma p \to QQ(W_{\gamma h})}\, d\omega$$

$Q\overline{Q}$ (LHC)	Collinear pQCD	CGC model
$c\bar{c}$	16 μb	5 μb
$b\bar{b}$	230 nb	110 nb

Goncalves, Machado Phys. Rev. D71 (2005)

Diffractive Photoproduction of heavy quarks

- Advantage of diffractive photoproduction
  - Clear final state defined by two rapidity gaps

Goncalves, Machado Phys. Rev. D75 (2007)

	pp	pPb	PbPb
$c\bar{c}$	92 nb	54 μb	59 mb
$b\bar{b}$	0.2 nb	0.09 μb	0.01 mb

pPb mode: L = 10^{29} $cm^{-2}s^{-1}$ → R ($c\bar{c}$) ~ 5 Hz

Acceptance ~ 10 %, Efficiency ~ 50 % → R($c\bar{c}$)~20k per day

Heavy quarks can also be produced by central exclusive diffraction, ie two pomeron fusion → harder spectrum of quarks, hence could be disentangled in p_T spectrum

Conclusions, outlook

- ALICE has unique opportunity to do soft diffractive physics @LHC
- Diffractive trigger defined by two rapidity gaps
- Neutral energy measurement at 0^0
- Phenomenology of Pomeron/Odderon
- Gluon saturation in heavy-quark photoproduction
- Photon-Photon physics